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Literature Review: Long-Term Complications of the Neurogenic Bladder

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Abstract This is a review of the most recent literature on the long-term complications of the neurogenic bladder (NGB). It is widely accepted that this condition, when left untreated, has a natural history that has a potential for causing deterioration of renal function over time. Consensus has not been reached regarding what patient profiles are at highest risk for these complications, as well as what surveillance strategies should be adopted. Chronic kidney disease (CKD) may be more prevalent in the NGB population than previously reported in the literature, as creatinine may not accurately reflect true renal function in these patients. Risk factors for upper urinary tract (UUT) deterioration include loss of bladder compliance, repeated bouts of pyelonephritis, and presence indwelling catheterization. Reduced access to urologic care and lack of adequate surveillance are also correlated with increased risk of upper tract complications. The urodynamic evaluation (urodynamic study (UDS)) has an important role in diagnosing the patient's underlying bladder pathology, but surveillance with UDS has not yet been linked to improved outcomes. Particularly vulnerable are those patients with decreased functional status or those requiring input from a multidisciplinary team. Some patients develop refractory NGB and UUT risk or overt deterioration. Treatment options that can offer benefit include onabotulinum A injections, augmentation cystoplasty with or without sling placement, or urinary diversion.

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Introduction

The neurogenic bladder (NGB) has a variable natural history depending on the underlying etiology. Over time, patients can start to demonstrate changes—often in the upper and lower urinary tract. The underlying causes of NGB may confer different risk profiles for long-term complications in these patients, and as such, it has been difficult to determine the actual risk to specific NGB populations. What is true, however, is that potentially devastating long-term complications are observed in these patients and that vigilant long-term follow-up strategies may be beneficial in diagnosing and often preventing these complications.

Currently, the established goals of management of the patient with NGB are [1]: (1) preservation or improvement in upper urinary tract (UUT) function, (2) absence or control of infection, (3) maintenance of a low pressure bladder that is both continent and capable of emptying well, (4) avoidance of indwelling catheter, and (5) management in line with the social and vocational goals of the patient [1].

Purpose of This Review

We aim to critically appraise the most current available evidence regarding the incidence of common long-term complications of NGB, such as renal failure, urinary incontinence, and urinary stone formation, as well as to describe the management and surveillance strategies to prevent long-term complications in high-risk patients within this population. Other long-term concerns relevant to this discussion, such as the risk of malignancy over time, are discussed further in another article in this edition.

We will also discuss management strategies for the "end-stage" NGB, to highlight outcomes and avoidance of complications in patients that have not benefited from other treatment attempts.

Description of Complications

Renal Failure Upper urinary tract (UUT) deterioration is one of the most feared complications of NGB. Several decades ago, almost 50 % of patients with spinal cord injury (SCI) died of renal failure and uremia secondary to NGB [2]. Currently, the NGB populations identified as the highest risk for UUT deterioration are SCI, transverse myelitis, spina bifida (SB), and men with multiple sclerosis (MS) [3–8]. Long-term data on untreated urinary storage and emptying problems in children with SB have been associated with long-term impairment of renal function [9, 10]. Previous literature suggests that renal failure may be more likely to occur in patients with NGB because of repeated bouts of pyelonephritis, bladder dysfunction related to loss of bladder compliance, hydronephrosis, and calculous disease [11], and Fischer et al. confirm these findings in a cross-sectional analysis of veterans with SCI across all VA facilities in 2006 [12••]. In their report, they found that among 9333 SCI patients, the proportion with chronic kidney disease (CKD) was around 35 %. The prevalence among veterans without SCI is around 20 %. Older age, Caucasian race, and female gender were associated with increasing odds of CKD. Veterans with SCI and CKD also had a greater burden of other chronic health conditions (diabetes, cardiovascular disease, and hypertension) than patients with normal glomerular filtration rate (GFR). In addition, duration of injury >10 years was associated with *decreased* odds of CKD, which may be indicative of survivor effect.

Fischer's study also highlights the fact that the currently used equations for estimating renal function overestimate GFR in the NGB population, as many of these patients, particularly quadriplegics, have decreased muscle mass due to disability-related muscle atrophy [12••]. After SCI, there is a notable and rapid loss of muscle mass below the level of the lesion, which is noticeable as early as 6 weeks post-injury [13].

In 2010, a correction to the Modification of Diet in Renal Disease (MDRD) and Cockcroft-Gault (CG) was validated in the SCI population through a retrospective diagnostic accuracy study, which allows for a better estimation of GFR among SCI patients [14]. In the Veteran's Affairs study, the proportion of patients with CKD was threefold higher using the corrected MDRD equation (35 versus 10.2 %). As a cross-sectional study, this report is limited to those patients that had a coded diagnosis of CKD, and as such, we may be observing an underestimation of the true prevalence of CKD.

Zhang and Liao examined risk factors for UUT damage in 150 patients with SCI in a prospective cohort. UUT abnormalities included any grade vesicoureteral reflux (VUR), hydronephrosis, and elevated serum creatinine. These abnormalities were present in 23 patients (65.7 %) in the spontaneous voiding group and in ten patients (20 %) of the intermittent catheterization (IC) group, 15 patients (78.9 %) with an indwelling catheter, and seven patients (87.5 %) with a suprapubic catheter. They found as significant predictors for UUT deterioration the following risk factors: lumbosacral SCI and chronic indwelling catheterization (both urethral and suprapubic) [15]. An underlying reason for this finding may be that impaired bladder compliance is likely the actual risk factor for UUT deterioration. Patients with indwelling catheters may have failed other management strategies, and indwelling catheterization itself is a proxy for decreased bladder and overall functionality.

While CKD continues to be prevalent in the NGB population, Osterthum et al., in a multicenter prospective cohort study of 225 SCI patients, reported cardiovascular and pulmonary to be more prevalent causes of death in SCI patients within the first 5 years after their first inpatient rehabilitation. This starkly contrasts with reports from decades earlier, when renal failure was the most frequent cause of death in patients with SCI [16] and may reflect better NGB care in recent decades. Specifically, utilization of IC and improvement in surveillance strategies are thought to contribute to the decreasing rates of death from renal failure in the NGB population.

Other NGB populations in addition to SCI are also known to be at high risk for UUT damage and renal failure. Capitanucci et al. reported on their long-term follow-up of patients with SB, reporting follow-up to 14 years. They documented the following rates of complications in this patient population: UUT deterioration occurred in 15 %, and renal failure occurred in 7.5 % [17]. De Seze and colleagues, in a 2007 systematic review of 17 articles reporting UUT findings, report the prevalence of UUT complications in 1200 patients with MS. They note that most studies are retrospective in nature but suggest that there is an increasing prevalence of UUT complications with time from disease onset. Reported UUT findings were mostly vesicoureteral reflux (VUR) and hydronephrosis, and combined, these changes were reported in 0.9 to 17 % of study patients [18••].

Incontinence Urinary incontinence may result in difficult management dilemmas for patients with NGB given the impaired mobility caused by their underlying neurologic condition. Incontinence—whether related to detrusor overactivity, stress, or overflow—is a dual offender, as it not only causes medical morbidity but also causes a high degree of psychosocial stress, including problems with self-esteem, social isolation, and difficulty with employment. This can quickly spiral, leading to diminished rehabilitation potential from the underlying neurologic condition [19]. Around 50 % of SCI patients, when questioned, report some degree of bothersome urinary incontinence [20]. In studies focused on the MS population, up to 21–50 % of patients experience frequent episodes of urinary incontinence [21]. For adult patients with SB, incontinence rates are higher, with approximately 45–70 % of patients reporting some degree of urinary leakage [10].

Stone Disease Zhang and Liao reported that when divided into two groups (catheter free versus indwelling catheter), there was a higher rate of bladder calculi in patients with an indwelling catheter (38.3 versus 81.5 % respectively, $p<0.001$) [15]. Patients with NGB are at a higher risk of stone formation and bilateral stone disease. In SCI patients, the risk of stone formation is 7–20 % over a period of 8–10 years, and they have very high rates of stone recurrence. A 72 % recurrence rate was reported in one case-control study at 2 years [22, 23], with other studies reporting recurrence rates between 35 and 64 % [24]. Despite improvements in bladder drainage, antibiotic usage, and upper tract imaging, the incidence of kidney stones over the past decade has remained the same [25]. One explanation is that decreases in stone episodes may be masked by improved disease ascertainment. Even with improvement in the number of symptomatic stone episodes, treatment of upper tract calculi in these patients can be difficult due to the anatomic implications as well as coexisting medical comorbidities. SCI was independently associated with development of systemic inflammatory response syndrome (SIRS) in a case-control study of percutaneous nephrolithotomy outcomes (PCNL). In addition, calculous disease in the NGB patient is associated with impaired renal function, which, in some studies, has been observed in 28–32 % of NGB patients with nephrolithiasis [23, 24].

It is unclear why certain patients tend to develop stones while others are spared. Rates of bacteriuria have been compared in stone formers versus non-stone formers, and no significant differences have been found. Over time, the stone composition distribution has changed, with a decreasing prevalence of struvite upper tract stones [23, 24].

Risk Factors for Long-Term Complications

Bladder Management Method In the Model SCI database, urologic complications and hospitalizations were evaluated in a large patient cohort. These were compared based on the type of bladder management. In this population, indwelling catheters were associated with an increased rate of urologic complications, which is in line with other studies that suggest that bladder management method is associated with risk of long-term complications [15, 19, 26, 27]. Specifically, indwelling catheter use in this study was found to be associated with more hospitalizations due to infection and decubitus ulcers. In addition, patients with indwelling catheters were found to have poorer psychosocial scores and also reported greater incontinence episodes than patients who were managed with IC. Initially, this sounds counterintuitive, but other studies also suggest that patients with indwelling catheters can have significant incontinence [20]. This finding may be indicative of the poor functional status of these patients, who, in addition to a debilitated condition, may be unable to care for themselves and do not have appropriate supportive care [28•]. Patients with worse bladder physiology may also be managed with indwelling catheters because of refractory urinary incontinence that cannot be managed in a satisfactory way with IC.

Catheter use can also be a proxy for greater physical disability or disease progression for NGB patients. The North American Research Committee on Multiple Sclerosis (NARCOMS) performed a cross-sectional survey of 9700 MS patients, in which 37 % of patients reported using catheters for assistance with bladder emptying, and this was associated with advanced disease [29]. Most patients with MS who are managed with catheterization use them intermittently, although the proportion of patients with MS who utilize indwelling catheters increases over time and throughout disease progression.

It is unclear if type of indwelling catheter affects the presentation or severity of NBG complications. A 2013 systematic review of the literature examined the relevant literature comparing urethral to suprapubic catheterization. They reported no differences among either bladder drainage method with regard to UTI rates, UUT complications, bladder stones, or malignancy. When quality of life outcomes were examined, the results suggested that patients with indwelling catheters often feel unprepared to care for the catheter, reporting the placement as an initially negative experience, especially in relation to their altered body image and perceived lack of provider support. Although urethral and skin problems are well documented in urethral catheterization, qualitative data suggest that patients perceive inadequate support in managing suprapubic catheter-related exit site granulation, bleeding, and other skin care issues. The authors emphasize that most studies in the review are retrospective and do not report findings in a consistent way to permit generalized conclusions, highlighting a need to tailor the decision for indwelling catheterization to each patient, with emphasis on patient counseling, supportive care, and understanding of increased risk of complications [30].

Cardenas et al. compared urodynamic findings amongst different methods of bladder management and found that maximum detrusor pressure decreased over time in patients managed with an external urine collection device [31]. In a prospective cohort of 246 patients with traumatic SCI, patients with higher level and more complete injuries were found to be more likely to be managed with an indwelling catheter and to have a greater rate of urologic complications. Higher-level injuries may impede the patient from performing IC. This study suggests that it is not the level of injury, but rather the state of the bladder that confers the risk of UUT deterioration [32•].

Type of Neurologic Injury

Spinal Cord Injury The risk association between SCI and UUT damage leading to renal failure has been well accepted. Belluci et al. demonstrated no statistical difference in the rates of abnormal urodynamic findings in patients who were ambulatory versus patients who were wheelchair bound [33], indicating that some ambulatory patients still were at risk for low bladder compliance. Consequently, it is recommended that all SCI patients, independent of injury location or completeness of injury, should receive the same follow-up and surveillance.

In their large study of US claims data, Manack et al. documented that >21 % of NGB patients in the sample were diagnosed with lower urinary tract infections and 8 % were hospitalized for sepsis. When divided into subcohorts, proportionately more SCI patients were hospitalized (42.3 %) than the NGB cohort (33.3 %) and the MS subcohort (21.4 %) [34]. Most large epidemiologic studies on NGB have focused on SCI, but caution should be taken when generalizing findings in this population to the other subgroups of NGB patients.

Multiple Sclerosis In the NARCOMS survey of the MS population, 65 % of the patients reported moderate to severe lower urinary tract symptoms, most prevalent in patients with secondary progressive MS [29]. For most patients with MS, the mean time to onset of urinary symptoms is 6–8 years, but some will experience changes within 2 years [21, 35–37]. Earlier onset of urinary symptoms portends a worse disease outcome [21, 35]. Reports suggest that the location of demyelinating lesions is associated with onset and progression of urinary symptoms [21, 38, 39]. Thus far, location of demyelinating lesion cannot reliably predict urinary symptoms, urodynamic findings, or risk of long-term complications. Detrusor-sphincter dyssynergia (DSD) is the only urodynamic finding that has demonstrated a strong correlation with MS lesions developing in the cervical spinal cord, but DSD has not proven to be a predictive finding of longer-term outcomes, as urinary symptoms in the MS patient can change considerably over time [21]. Nonetheless, DSD is one urodynamic parameter that, once present on urodynamic study (UDS), remains stable over time, increasing its prevalence with time from disease onset. In addition, it has been associated with pyelonephritis, which has also correlated with disease progression in MS patients [18••, 40]. Currently, the American Urological Association (AUA) Urodynamic Guidelines place male patients with MS in the high-risk category for long-term UUT deterioration [7], largely based on descriptive studies of UDS findings in this population, which documented higher voiding pressures, higher detrusor leak point pressures, and lower bladder compliance in male patients with MS and DSD [8, 39, 41, 42]. There is no consensus on whether MS confers a defined risk of UUT deterioration, but a recent review of the existing literature does suggest its increasing prevalence, particularly 6–8 years after disease onset [18••].

Spina Bifida Because of the advances in medical and urologic care, many SB patients are now surviving into adulthood. However, mortality for these patients increases as they transition into the adult patient population. Adolescence in the SB patient is associated with an increase in maximum cystometric capacity, detrusor pressure, and detrusor leak point pressure, which may be explained by hormonally driven changes to the lower urinary tract. Although multidisciplinary pediatric care for the SB patient has been successful at reducing complications, the data suggests that transitioning to adult care increases morbidity for patients. A study of transitional care populations conducted in Canada reported that SB patients, of all of the transitioning populations, were the most highly educated group, had the highest percentages living alone (23.1 %), and had the highest percentages of those working full-time (30.8 %). However, those adults with SB had the worst self-rated health and only one third of them had regular urologic care [43].

Long-term fatal complications for the adult SB patient include, in addition to renal failure and sepsis, neurologic complications such as hydrocephalus and epilepsy. In a review article focusing on transitional care, Le et al. delineate, in their expert opinion, the five key elements of a satisfactory transition program for this population: preparation, flexible timing, care coordination, transitional clinic visits, and interested health care providers [10, 43].

The Role of Urologic Surveillance and Its Association with Long-Term Complications

Averbeck et al., in a systematic review of the urologic literature regarding urologic surveillance in the NGB population, confirm that there is a lack of high-level evidence studies. Guidelines, for the most part, are based on expert opinion [32•], and there is no consensus as to the ideal testing that should be performed during screening. In a 2012 systematic review, the authors evaluate 11 articles evaluating urologic surveillance for UUT complications after SCI. Renal ultrasound was found to be a cost-effective imaging modality that had better sensitivity than IVP or renal scan at diagnosing anatomical abnormalities of the UUT [44]. The authors did not report sufficient evidence in the literature to recommend an optimal frequency for UDS. In addition, serum creatinine was not found to be a sensitive test to detect renal impairment, and the authors advise that creatinine clearance can be used if applying the proper correction factors necessary for this population. Of note, the corrective factor for the MDRD equation has only been validated in the SCI population and cannot be extrapolated to the rest of the NGB population [14].

However, there is evidence that surveillance is associated with reduced long-term complications in NGB. Despite an improving awareness of the long-term complications of NGB and implementation of bladder management strategies that have slowed the progression of complications, many patients with NGB still do not receive adequate screening, and there is staggering variability in the types of surveillance recommendations in the literature. However, its utility has been established in many studies. In an early report of surveillance, Waites et al. found that serial examination after SCI is important after SCI, as it can help preserve long-term renal function [45].

In another large retrospective cohort of SCI patients, Cameron et al. used a 5 % Medicare sample to evaluate the patterns of urological follow-up and predictors of urological complications [46••]. Using the minimum adequate screening recommendation, composed of a urologist visit, serum creatinine, and UUT imaging study, the authors report that only 24.6 % of the patients received adequate screening during a 2-year period. Twenty-five percent of the patients in the sample were found to have at least one de novo moderate to severe urologic complication, defined in the study as having the potential to cause UUT deterioration (moderate) or being life-threatening or requiring major surgery (severe). Included complications were CKD (5.8 %), recurrent cystitis (21.1 %), and high-stage pressure ulcers (7 %), which are known to correlate with refractory urinary incontinence [46••]. Male gender, younger age, African American race, paraplegia, and receiving some or all forms of urologic surveillance were associated with increased role of complications.

Access to tertiary care is extremely important for patients with NGB. The presence of a multidisciplinary care team and frequent access to psychosocial support are likely to play a large role in the avoidance of complications. Further studies are needed to correlate improved urological surveillance with decreased incidence of complications.

The Urodynamic Evaluation and Its Role in Predicting Long-Term Complications

The AUA guideline on urodynamics recommends routine UDS on the following populations with NGB, who have a confirmed risk of UUT deterioration: SCI, transverse myelitis, spina bifida (SB), and men with multiple sclerosis [7]. The European Association of Urology (EAU), in its Guidelines on Neuro-Urology, recommends urodynamic evaluation as a "mandatory baseline diagnostic study and in high-risk patients, should be done at regular intervals" [32•]. For high-risk patients, they recommend a urodynamic evaluation at least once per year [47]. The benefit of UDS lies in its ability to detect indolent problems before they start to effect complications. However, there is a paucity of quality evidence to support a specific follow-up strategy in the NGB patient, and we do not yet know whether adherence to surveillance guidelines improves specific outcomes.

A cohort of 246 patients with traumatic SCI who had at least 5 years of convalescence from their initial injury underwent prospective urodynamic evaluation, which was compared to their earliest available UDS [48]. The authors report that most UDS resulted in findings that were within the limits of safety. Interestingly, they note a trend from spontaneous voiding to IC, as well as increasing utilization of onabotulinum toxin A, alongside a parallel decrease in the use of anticholinergic medication. They observe a low rate of UUT findings in these patients on renal ultrasound, reporting normal renal ultrasounds in all but four patients who had prior renal scarring. The incidence of VUR was around 5 %, and this was found to be low grade [48]. Despite the low rate of concerning UDS findings in the study, the authors do report that modification of bladder management was necessary in 25 % of patients in the cohort and advocate for regular UDS evaluation in SCI patients [48].

Continued urodynamic surveillance for other NGB types is also recommended in the literature. Vainrib et al. assessed urodynamic findings in adult patients with NGB and SB before and after augmentation enterocystoplasty. Most patients maintain low bladder pressures for >10 years. Close long-term follow-up is advocated, as elevated detrusor pressures can be seen even with lower urinary tract reconstruction [49]. Ciancio et al. studied the urodynamic pattern changes in patients with multiple sclerosis. Over half (55 %) of the patients had a change in their bladder compliance during the study interval between UDSs. The authors recommended a regularly spaced schedule of urodynamic evaluation to reduce the frequency of complications and to improve management [8].

At our institution, fluoroscopic urodynamic evaluation is performed as a baseline in all high-risk NGB patients: traumatic SCI, SB, and MS patients with an elevated post-void residual or history of urinary retention. Fluoroscopy is used to determine if the measured bladder compliance is being underestimated by VUR or bladder diverticulum. After the initial screening study, need for repeat urodynamic studies is determined on a case-by-case basis, taking into consideration type of NGB, length of time with disease, patient symptoms, incidence of UTI in the previous year, catheter use, creatinine clearance, and renal ultrasound evaluation. SCI and spinal bifida patients with a high compliance bladder and no urinary symptoms are screened every 1–3 years. MS patients with high compliance, atonic bladders do not undergo additional UDS testing if symptoms resolve with a intermittent catheterization routine. Specific urodynamic findings that we find suggestive of UUT risk that require more frequent UDS testing include the following: changes in compliance, presence of VUR, reduction in cystometric capacity, and elevated detrusor leak point pressure greater than 40 cm H_2O [50].

Alternatives to the Urodynamic Evaluation UDS is invasive and carries a cost burden, but it is the best reliable method to assess bladder function. Other alternative methods of functionally evaluating the bladder have been examined. In a study of 60 SCI patients, bladder wall thickness on ultrasound was examined to determine whether other forms of bladder evaluation could be predictive of bladder function [51]. The authors found that a thickness of 0.97 mm or less could predict with 91.7 % sensitivity and 63 % specificity the absence of risk factors such as poor compliance and high leak point pressure for upper tract damage. Although promising as a less-invasive method of measuring bladder function, this technique cannot predict neurogenic detrusor overactivity. In addition, there is a large degree of operator variability in estimating bladder wall size on ultrasound. At our institution, we do not use ultrasound bladder thickness as an alternative for urodynamic testing, but the modality holds promise as a less-invasive option for the lower-risk patient.

Surgical Management of the End-Stage Neurogenic Bladder

Botulinum Toxin Injections The advent of onabotulinum toxin A injections has decreased the utilization of other, more invasive, forms of restoring bladder storage functionality. As the time interval increases from the initial onset of NLUTD, the utilization of botulinum toxin injections increases [52]. Although this treatment modality has ever-increasing popularity as a Food and Drug Administration-approved treatment for refractory neurogenic detrusor overactivity, several important concerns remain, such as optimal injection technique, dosage, timing of repeat injections, long-term safety, and exact mechanism of action [48, 53] Currently, 200 units is the standard dose, with timing of repeat dosing contingent upon symptomatic recurrence, provided that any abnormalities in bladder compliance are improved on follow-up UDS.

Augmentation Cystoplasty Although the utilization of augmentation cystoplasty has decreased as more patients undergo onabotulinum A injections, there is still a role for the procedure in the patient with refractory symptoms. The procedure can be combined with a catheterizable stoma in the case of a devastated urethra, fistulous disease, or other process that prohibits the use of the patient's native urethra. Long-term outcomes are favorable, with the longest retrospective case series reporting preserved continence after 10 years of follow-up. Overall, the current literature reports a 77 % continence rate (range 55–88 %), although the NGB subgroup has higher continence success rates [56]. However, bladder compliance and maximum cystometric capacity can vary over time, even with augmentation, making surveillance important even after the initial problem is resolved [57]. In a study with a minimum of 10 years of follow-up data, Gurung and colleagues described the long-term results of augmentation cystoplasty, reporting statistically significant improvements in MCC and bladder compliance that were maintained at 10 years. No patients developed UUT deterioration. As with other studies on augmentation cystoplasty outcomes, the most common complications were bladder stones and urinary tract infections [56, 58].

Urinary Diversion Cystectomy with urinary diversion can be the last treatment option for patients with NGB and severe lower urinary tract symptoms who have not responded to less-invasive forms of treatment [54–59, 60•, 61]. Because the primary goal of a cystectomy performed for this indication is to decrease the patient's morbidity, understanding the outcomes and potential complications is essential to ensure proper patient selection for the intervention.

There is considerable data in the literature regarding radical cystectomy and urinary diversion in bladder cancer patients demonstrating high morbidity and readmission rates associated with the procedure. Even with improvements in outcomes, the mortality of cystectomy today is between 1 and 2 % and the perioperative morbidity of this procedure remains high [60•]. However, there is limited data on the perioperative morbidity and mortality rates for cystectomies performed for non-malignant indications [61]. Most data is retrospective and pooled among patients with varying benign urologic conditions in addition to NGB. There is also no long-term survival data on patients who undergo cystectomy and urinary diversion for non-malignant indications. Despite this lack of data, NGB patients are the largest population that undergoes cystectomy and urinary diversion for benign indications, emphasizing the need for further investigation of the outcomes for patients requiring urinary diversion.

Conclusion

Active research in the area of NGB patient risk stratification, access to care, and outcomes of surveillance strategies and treatments will greatly improve the urologic care provided to these patients. While current guidelines are mostly based on expert opinion, current consensus suggests that all NGB patients warrant a baseline evaluation with a urologist visit, renal ultrasound, and urodynamic studies, with closer follow-up surveillance strategies aimed at targeting the higher-risk patients with impaired bladder compliance, indwelling catheters, and recurrent urinary tract infections, regardless of underlying urologic diagnosis. A multidisciplinary team that is cognizant of the psychosocial stressors that also play a role is particularly important in patients with no supportive care or in patients who are transitioning from pediatric to adult NGB populations. Lastly, the patient with refractory NGB symptoms and an at-risk UUT may need surgical management for safety. More studies are needed to determine whether these interventions for end-stage NGB patients improve outcomes and survival.

Compliance with Ethics Guidelines

Conflict of Interest Y. Santiago-Lastra declares no conflict of interest.

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Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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